# 14-Bit and 16-Bit Parallel Low Glitch Multiplying DACs with 4-Quadrant Resistors

## FEATURES

- **True 16-Bit Performance Over Industrial Temperature Range**
- **DNL and INL: 1LSB Max**
- **On-Chip 4-Quadrant Resistors Allow Precise 0V to 10V, 0V to –10V or ±10V Outputs**
- **Pin Compatible 14- and 16-Bit Parts**
- Asynchronous Clear Pin
  - LTC1591/LTC1597: Reset to Zero Scale
  - LTC1591-1/LTC1597-1: Reset to Mid-Scale
- **Glitch Impulse < 2nV-s**
- Low Power Consumption: 10µW Typ
- Power-On Reset
- 28-Lead SSOP Package

## APPLICATIONS

- Process Control and Industrial Automation
- Direct Digital Waveform Generation
- Software-Controlled Gain Adjustment
- Automatic Test Equipment

## DESCRIPTION

The LTC®1591/LTC1597 are pin compatible, parallel input 14-bit and 16-bit multiplying current output DACs that operate from a single 5V supply. INL and DNL are accurate to 1LSB over the industrial temperature range in both 2- and 4-quadrant multiplying modes. True 16-bit 4-quadrant multiplication is achieved with on-chip 4-quadrant multiplication resistors.

These DACs include an internal deglitcher circuit that reduces the glitch impulse to less than 2nV-s (typ). The asynchronous $\overline{CLR}$ pin resets the LTC1591/LTC1597 to zero scale and LTC1591-1/LTC1597-1 to mid-scale.

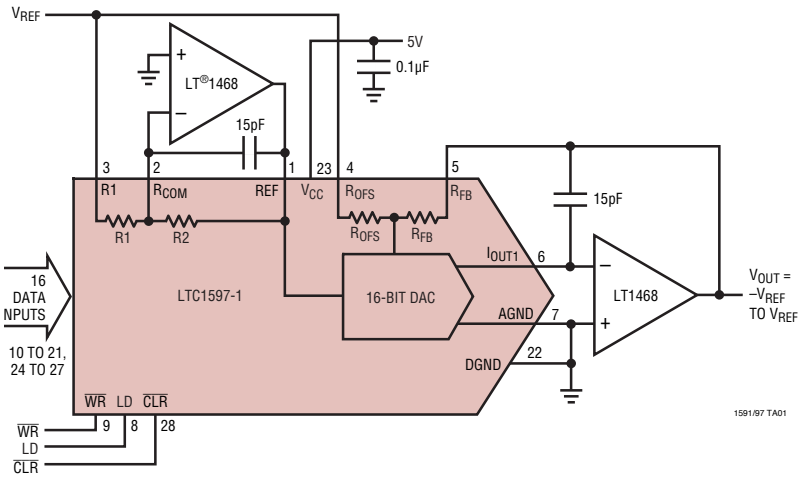
The LTC1591/LTC1597 are available in the 28-pin SSOP package and are specified over the industrial temperature range.

For serial interface 16-bit current output DACs refer to the LTC1595/LTC1596 data sheet.

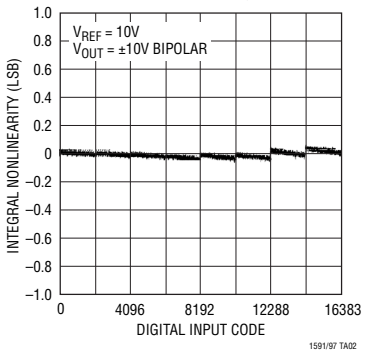


## TYPICAL APPLICATION

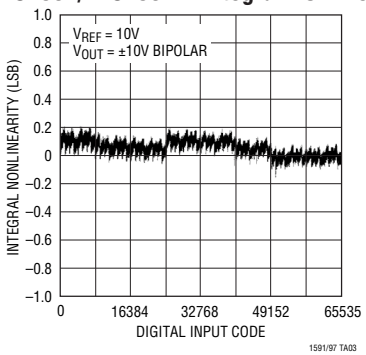
**16-Bit, 4-Quadrant Multiplying DAC with a Minimum of External Components**




**LTC1591/LTC1591-1 Integral Nonlinearity**




**LTC1597/LTC1597-1 Integral Nonlinearity**



## ABSOLUTE MAXIMUM RATINGS (Note 1)

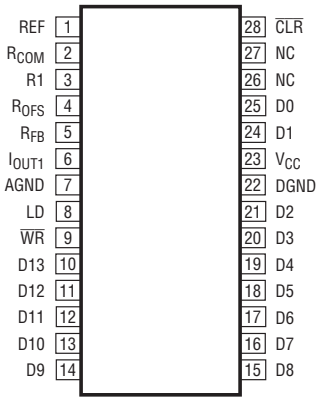
$V_{CC}$ to AGND .....–0.5V to 7V
$V_{CC}$ to DGND ..... –0.5V to 7V
AGND to DGND ..... $V_{CC}$ + 0.5V
DGND to AGND ..... $V_{CC}$ + 0.5V
REF, $R_{OFS}$, $R_{FB}$, R1, $R_{COM}$ to AGND, DGND ..... ±25V
Digital Inputs to DGND ..... –0.5V to ($V_{CC}$ + 0.5V)
$I_{OUT1}$ to AGND ..... –0.5V to( $V_{CC}$ + 0.5V)
Maximum Junction Temperature ..... 125°C

Operating Temperature Range
LTC1591C/LTC1591-1C
LTC1597C/LTC1597-1C ..... 0°C to 70°C
LTC1591I/LTC1591-1I
LTC1597I/LTC1597-1I ..... –40°C to 85°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

## PIN CONFIGURATION

LTC1591

TOP VIEW

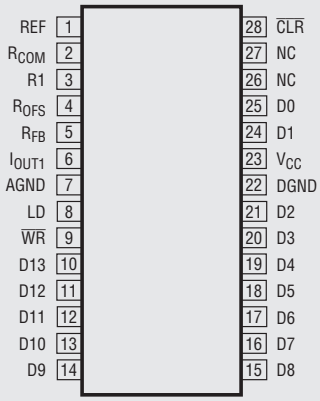



G PACKAGE
28-LEAD PLASTIC SSOP

$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 95°C/ W

LTC1591

TOP VIEW



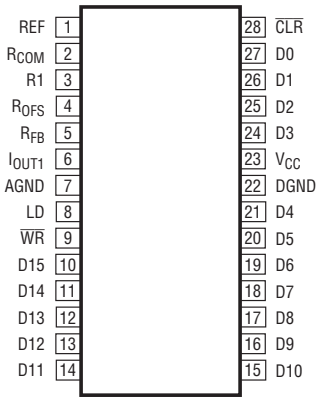

N PACKAGE
28-LEAD NARROW PDIP

$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 70°C/W

**OBSOLETE PACKAGE**

LTC1597

TOP VIEW

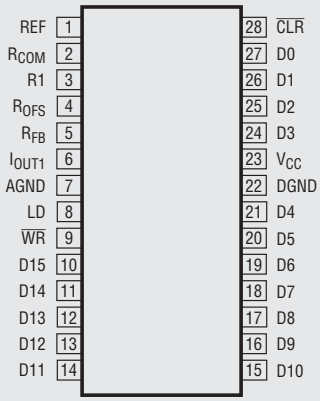



G PACKAGE
28-LEAD PLASTIC SSOP

$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 95°C/ W

LTC1597

TOP VIEW




N PACKAGE
28-LEAD NARROW PDIP

$T_{JMAX}$ = 125°C, $\theta_{JA}$ = 70°C/W

**OBSOLETE PACKAGE**

# ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL | PART MARKING | PACKAGE DESCRIPTION | TEMPERATURE RANGE |
|---|---|---|---|---|
| LTC1591CG#PBF | LTC1591CG#TRPBF | LTC1591CG | 28-Lead Plastic SSOP | 0°C to 70°C |
| LTC1591-1CG#PBF | LTC1591-1CG#TRPBF | LTC1591-1CG | 28-Lead Plastic SSOP | 0°C to 70°C |
| LTC1591IG#PBF | LTC1591IG#TRPBF | LTC1591IG | 28-Lead Plastic SSOP | –40°C to 85°C |
| LTC1591-1IG#PBF | LTC1591-1IG#TRPBF | LTC1591-1IG | 28-Lead Plastic SSOP | –40°C to 85°C |
| LTC1597ACG#PBF | LTC1597ACG#TRPBF | LTC1597ACG | 28-Lead Plastic SSOP | 0°C to 70°C |
| LTC1597-1ACG#PBF | LTC1597-1ACG#TRPBF | LTC1597-1ACG | 28-Lead Plastic SSOP | 0°C to 70°C |
| LTC1597BCG#PBF | LTC1597BCG#TRPBF | LTC1597BCG | 28-Lead Plastic SSOP | 0°C to 70°C |
| LTC1597-1BCG#PBF | LTC1597-1BCG#TRPBF | LTC1597-1BCG | 28-Lead Plastic SSOP | 0°C to 70°C |
| LTC1597AIG#PBF | LTC1597AIG#TRPBF | LTC1597AIG | 28-Lead Plastic SSOP | –40°C to 85°C |
| LTC1597-1AIG#PBF | LTC1597-1AIG#TRPBF | LTC1597-1AIG | 28-Lead Plastic SSOP | –40°C to 85°C |
| LTC1597BIG#PBF | LTC1597BIG#TRPBF | LTC1597BIG | 28-Lead Plastic SSOP | –40°C to 85°C |
| LTC1597-1BIG#PBF | LTC1597-1BIG#TRPBF | LTC1597-1BIG | 28-Lead Plastic SSOP | –40°C to 85°C |
| **OBSOLETE PACKAGE** | | | | |
| LTC1591CN#PBF | LTC1591CN#TRPBF | LTC1591CN | 28-Lead Narrow PDIP | 0°C to 70°C |
| LTC1591-1CN#PBF | LTC1591-1CN#TRPBF | LTC1591-1CN | 28-Lead Narrow PDIP | 0°C to 70°C |
| LTC1591IN#PBF | LTC1591IN#TRPBF | LTC1591IN | 28-Lead Narrow PDIP | –40°C to 85°C |
| LTC1591-1IN#PBF | LTC1591-1IN#TRPBF | LTC1591-1IN | 28-Lead Narrow PDIP | –40°C to 85°C |
| LTC1597ACN#PBF | LTC1597ACN#TRPBF | LTC1597ACN | 28-Lead Narrow PDIP | 0°C to 70°C |
| LTC1597-1ACN#PBF | LTC1597-1ACN#TRPBF | LTC1597-1ACN | 28-Lead Narrow PDIP | 0°C to 70°C |
| LTC1597BCN#PBF | LTC1597BCN#TRPBF | LTC1597BCN | 28-Lead Narrow PDIP | 0°C to 70°C |
| LTC1597-1BCN#PBF | LTC1597-1BCN#TRPBF | LTC1597-1BCN | 28-Lead Narrow PDIP | 0°C to 70°C |
| LTC1597AIN#PBF | LTC1597AIN#TRPBF | LTC1597AIN | 28-Lead Narrow PDIP | –40°C to 85°C |
| LTC1597-1AIN#PBF | LTC1597-1AIN#TRPBF | LTC1597-1AIN | 28-Lead Narrow PDIP | –40°C to 85°C |
| LTC1597BIN#PBF | LTC1597BIN#TRPBF | LTC1597BIN | 28-Lead Narrow PDIP | –40°C to 85°C |
| LTC1597-1BIN#PBF | LTC1597-1BIN#TRPBF | LTC1597-1BIN | 28-Lead Narrow PDIP | –40°C to 85°C |

Consult LTC Marketing for parts specified with wider operating temperature ranges.
Consult LTC Marketing for information on nonstandard lead based finish parts.

For more information on lead free part markings, go to: http://www.linear.com/leadfree/
For more information on tape and reel specifications, go to: http://www.linear.com/tapeandreel/

## ELECTRICAL CHARACTERISTICS

**$V_{CC}$ = 5V ±10%, $V_{REF}$ = 10V, $I_{OUT1}$ = AGND = DGND = 0V, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | | LTC1591/-1 MIN | LTC1591/-1 TYP | LTC1591/-1 MAX | LTC1597B/-1B MIN | LTC1597B/-1B TYP | LTC1597B/-1B MAX | LTC1597A/-1A MIN | LTC1597A/-1A TYP | LTC1597A/-1A MAX | UNITS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Accuracy** | | | | | | | | | | | | | |
| | Resolution | | ● | 14 | | | 16 | | | 16 | | | Bits |
| | Monotonicity | | ● | 14 | | | 16 | | | 16 | | | Bits |
| INL | Integral Nonlinearity | (Note 2) $T_A$ = 25°C | | | | ±1 | | | ±2 | | ±0.25 | ±1 | LSB |
| | | $T_{MIN}$ to $T_{MAX}$ | ● | | | ±1 | | | ±2 | | ±0.35 | ±1 | LSB |
| DNL | Differential Nonlinearity | $T_A$ = 25°C | | | | ±1 | | | ±1 | | ±0.2 | ±1 | LSB |
| | | $T_{MIN}$ to $T_{MAX}$ | ● | | | ±1 | | | ±1 | | ±0.2 | ±1 | LSB |
| GE | Gain Error | Unipolar Mode | | | | | | | | | | | |
| | | (Note 3) $T_A$ = 25°C | | | | ±4 | | | ±16 | | 2 | ±16 | LSB |
| | | $T_{MIN}$ to $T_{MAX}$ | ● | | | ±6 | | | ±24 | | 3 | ±16 | LSB |
| | | Bipolar Mode | | | | | | | | | | | |
| | | (Note 3) $T_A$ = 25°C | | | | ±4 | | | ±16 | | 2 | ±16 | LSB |
| | | $T_{MIN}$ to $T_{MAX}$ | ● | | | ±6 | | | ±24 | | 3 | ±16 | LSB |
| | Gain Temperature Coefficient | (Note 4) ΔGain/ΔTemperature | ● | | 1 | 2 | | 1 | 2 | | 1 | 2 | ppm/°C |
| | Bipolar Zero-Scale Error | $T_A$ = 25°C | | | | ±3 | | | ±10 | | | ±5 | LSB |
| | | $T_{MIN}$ to $T_{MAX}$ | ● | | | ±5 | | | ±16 | | | ±8 | LSB |
| $I_{LKG}$ | OUT1 Leakage Current | (Note 5) $T_A$ = 25°C | | | | ±5 | | | ±5 | | | ±5 | nA |
| | | $T_{MIN}$ to $T_{MAX}$ | ● | | | ±15 | | | ±15 | | | ±15 | nA |
| PSRR | Power Supply Rejection Ratio | $V_{CC}$ = 5V ±10 | ● | | ±0.1 | ±1 | | ±0.4 | ±2 | | ±0.4 | ±2 | LSB/V |

**$V_{CC}$ = 5V ±10%, $V_{REF}$ = 10V, $I_{OUT1}$ = AGND = DGND = 0V, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **Reference Input** | | | | | | | |
| $R_{REF}$ | DAC Input Resistance (Unipolar) | (Note 6) | ● | 4.5 | 6 | 10 | kΩ |
| R1/R2 | R1/R2 Resistance (Bipolar) | (Notes 6, 13) | ● | 9 | 12 | 20 | kΩ |
| $R_{OFS}$, $R_{FB}$ | Feedback and Offset Resistances | (Note 6) | ● | 9 | 12 | 20 | kΩ |
| **AC Performance (Note 4)** | | | | | | | |
| | Output Current Settling Time | (Notes 7, 8) | | | 1 | | µs |
| | Mid-Scale Glitch Impulse | (Note 12) | | | 2 | | nV-s |
| | Digital-to-Analog Glitch Impulse | (Note 9) | | | 1 | | nV-s |
| | Multiplying Feedthrough Error | $V_{REF}$ = ±10V, 10kHz Sine Wave | | | 1 | | $mV_{P-P}$ |
| THD | Total Harmonic Distortion | (Note 10) | | | 108 | | dB |
| | Output Noise Voltage Density | (Note 11) | | | 10 | | nV/√Hz |
| | Harmonic Distortion (Digital Waveform Generation) | Unipolar Mode (Note 14) | | | | | |
| | | 2nd Harmonic | | | 94 | | dB |
| | | 3rd Harmonic | | | 101 | | dB |
| | | SFDR | | | 94 | | dB |
| | | Bipolar Mode (Note 14) | | | | | |
| | | 2nd Harmonic | | | 94 | | dB |
| | | 3rd Harmonic | | | 101 | | dB |
| | | SFDR | | | 94 | | dB |

## ELECTRICAL CHARACTERISTICS

**The ● denotes specifications that apply over the full operating temperature range. $V_{CC}$ = 5V ±10%, $V_{REF}$ = 10V, $I_{OUT1}$ = AGND = DGND = 0V, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted.**

| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **Analog Outputs (Note 4)** | | | | | | | |
| $C_{OUT}$ | Output Capacitance (Note 4) | DAC Register Loaded to All 1s: $C_{OUT1}$<br>DAC Register Loaded to All 0s: $C_{OUT1}$ | ●<br>● | | 115<br>70 | 130<br>80 | pF<br>pF |
| **Digital Inputs** | | | | | | | |
| $V_{IH}$ | Digital Input High Voltage | | ● | 2.4 | | | V |
| $V_{IL}$ | Digital Input low Voltage | | ● | | | 0.8 | V |
| $I_{IN}$ | Digital Input Current | | ● | | 0.001 | ±1 | µA |
| $C_{IN}$ | Digital Input Capacitance | (Note 4) $V_{IN}$ = 0V | ● | | | 8 | pF |
| **Timing Characteristics** | | | | | | | |
| $t_{DS}$ | Data to $\overline{WR}$ Setup Time | | ● | 60 | | | ns |
| $t_{DH}$ | Data to $\overline{WR}$ Hold Time | | ● | 0 | | | ns |
| $t_{WR}$ | $\overline{WR}$ Pulse Width | | ● | 60 | | | ns |
| $t_{LD}$ | LD Pulse Width | | ● | 110 | | | ns |
| $t_{CLR}$ | Clear Pulse Width | | ● | 60 | | | ns |
| $t_{LWD}$ | $\overline{WR}$ to LD Delay Time | | ● | 0 | | | ns |
| **Power Supply** | | | | | | | |
| $V_{DD}$ | Supply Voltage | | ● | 4.5 | 5 | 5.5 | V |
| $I_{DD}$ | Supply Current | Digital Inputs = 0V or $V_{CC}$ | ● | | | 10 | µA |

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** ±1LSB = ±0.006% of full scale = ±61ppm of full scale for the LTC1591/LTC1591-1. ±1LSB = ±0.0015% of full scale = ±15.3ppm of full scale for the LTC1597/LTC1597-1.

**Note 3:** Using internal feedback resistor.

**Note 4:** Guaranteed by design, not subject to test.

**Note 5:** $I_{(OUT1)}$ with DAC register loaded to all 0s.

**Note 6:** Typical temperature coefficient is 100ppm/°C.

**Note 7:** $I_{OUT1}$ load = 100Ω in parallel with 13pF.

**Note 8:** To 0.006% for a full-scale change, measured from the rising edge of LD for the LTC1591/LTC1591-1. To 0.0015% for a full-scale change, measured from the rising edge of LD for the LTC1597/LTC1597-1.

**Note 9:** $V_{REF}$ = 0V. DAC register contents changed from all 0s to all 1s or all 1s to all 0s.

**Note 10:** $V_{REF}$ = $6V_{RMS}$ at 1kHz. DAC register loaded with all 1s.

**Note 11:** Calculation from $e_n = \sqrt{4kTRB}$ where: k = Boltzmann constant (J/°K), R = resistance (Ω), T = temperature (°K), B = bandwidth (Hz).

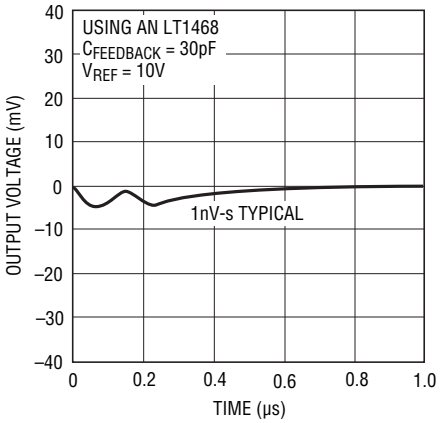
**Note 12:** Mid-scale transition code: 01 1111 1111 1111 to 10 0000 0000 0000 for the LTC1591/LTC1591-1 and 0111 1111 1111 1111 to 1000 0000 0000 0000 for the LTC1597/LTC1597-1.

**Note 13:** R1 and R2 are measured between R1 and $R_{COM}$, REF and $R_{COM}$.

**Note 14:** Measured using the LT1468 op amp in unipolar mode for I/V converter and LT1468 I/V and LT1001 reference inverter in bipolar mode. Sample Rate = 50kHz, Signal Frequency = 1kHz, $V_{REF}$ = 5V, $T_A$ = 25°C.

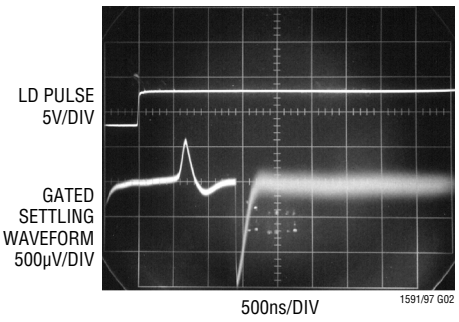
## TYPICAL PERFORMANCE CHARACTERISTICS (LTC1591/LTC1597)

### Mid-Scale Glitch Impulse



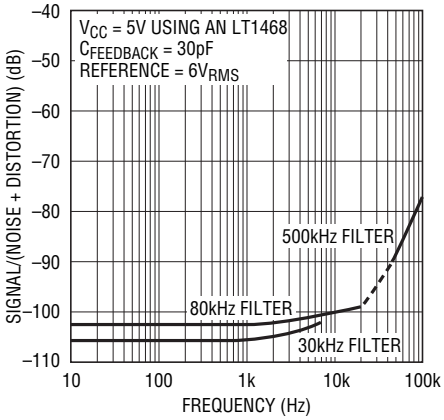

1591/97 G01

### Full-Scale Settling Waveform



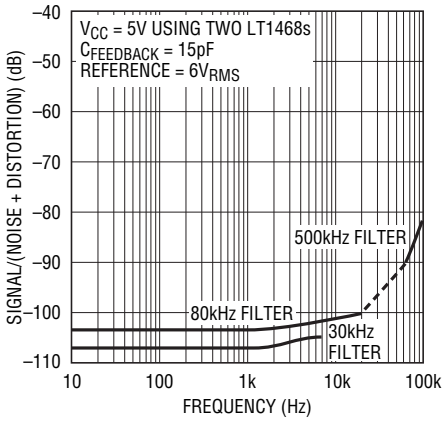

USING LT1468 OP AMP
$C_{FEEDBACK}$ = 20pF
0V TO 10V STEP

### Unipolar Multiplying Mode Signal-to-(Noise + Distortion) vs Frequency



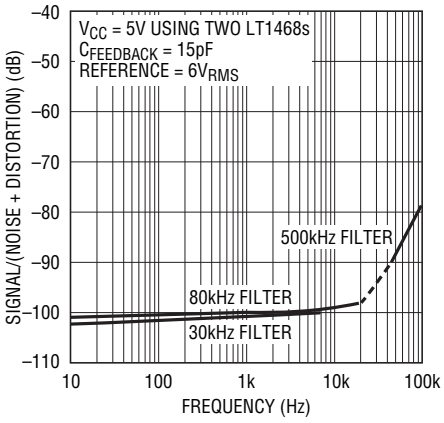

1591/97 G03

### Bipolar Multiplying Mode Signal-to-(Noise + Distortion) vs Frequency, Code = All Zeros



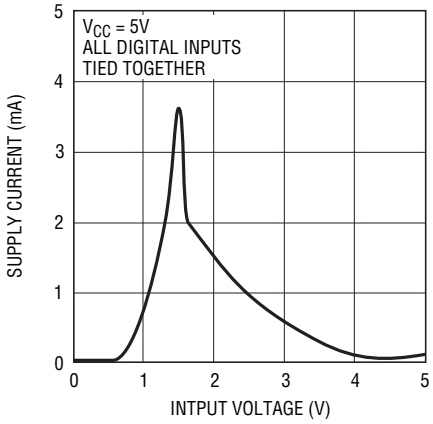

1591/97 G04

### Bipolar Multiplying Mode Signal-to-(Noise + Distortion) vs Frequency, Code = All Ones



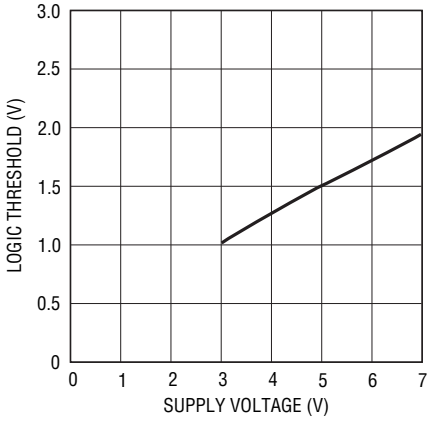

1591/97 G05

### Supply Current vs Input Voltage




1591/97 G06

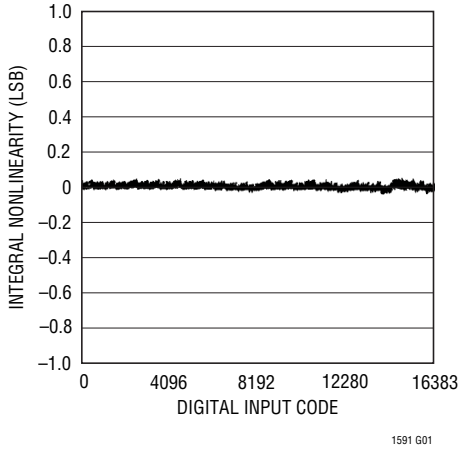
### Logic Threshold vs Supply Voltage



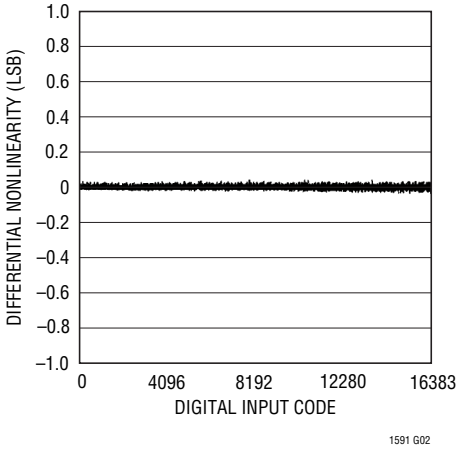

1591/97 G07

# TYPICAL PERFORMANCE CHARACTERISTICS (LTC1591)

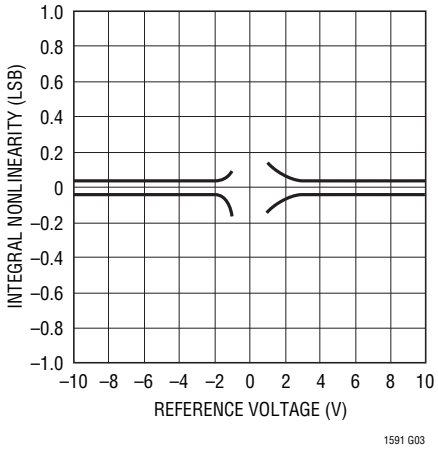
### Integral Nonlinearity (INL)



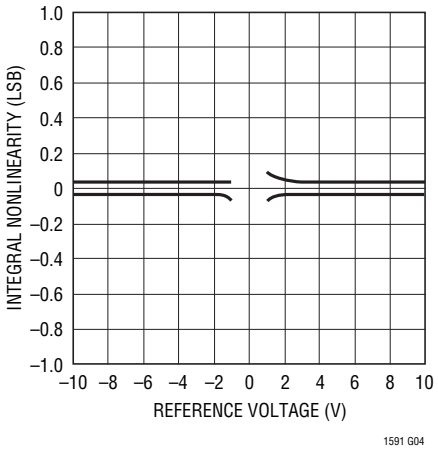

### Differential Nonlinearity (DNL)



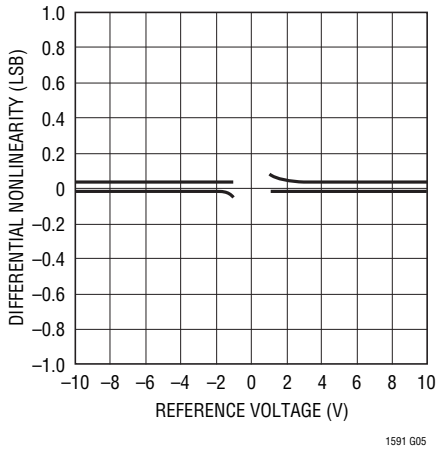

### Integral Nonlinearity vs Reference Voltage in Unipolar Mode



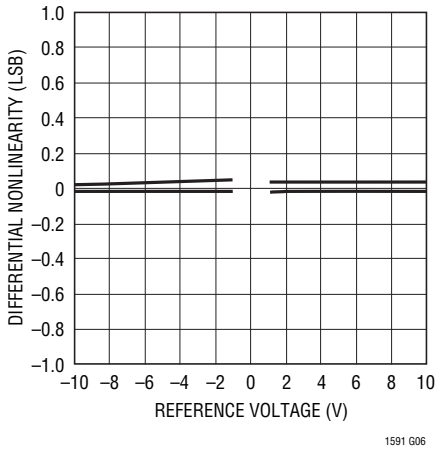

### Integral Nonlinearity vs Reference Voltage in Bipolar Mode



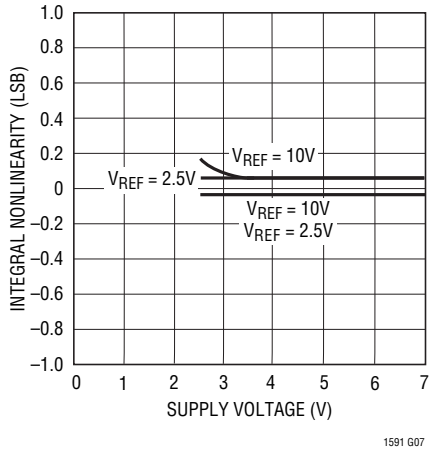

### Differential Nonlinearity vs Reference Voltage in Unipolar Mode



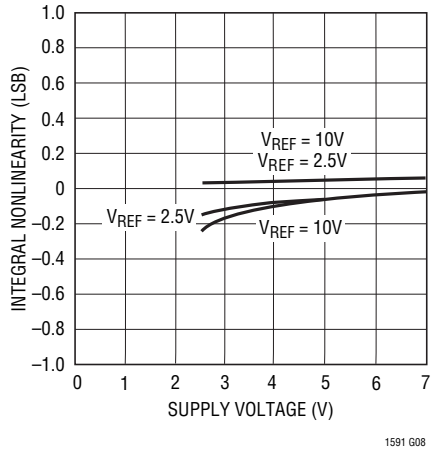

### Differential Nonlinearity vs Reference Voltage in Bipolar Mode



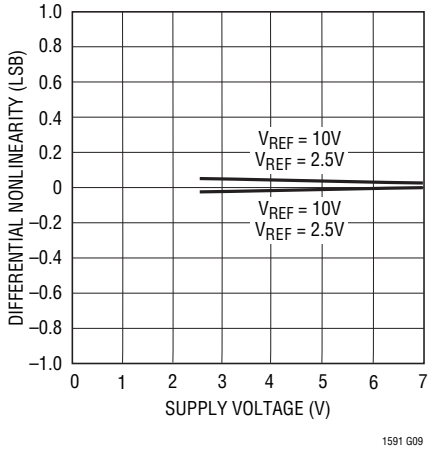

### Integral Nonlinearity vs Supply Voltage in Unipolar Mode




### Integral Nonlinearity vs Supply Voltage in Bipolar Mode

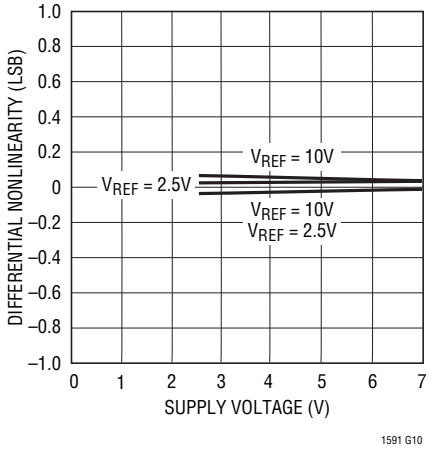



### Differential Nonlinearity vs Supply Voltage in Unipolar Mode

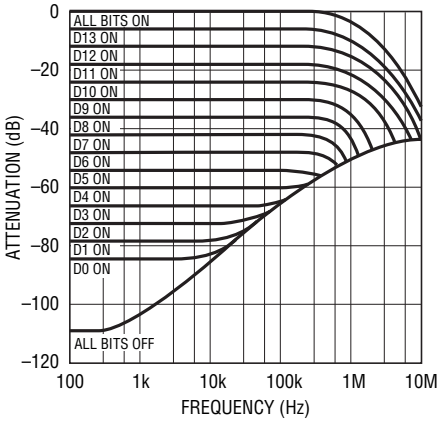


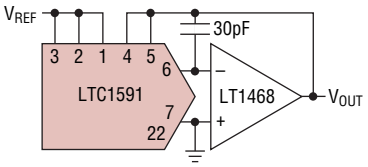
## TYPICAL PERFORMANCE CHARACTERISTICS (LTC1591)

### Differential Nonlinearity vs Supply Voltage in Bipolar Mode

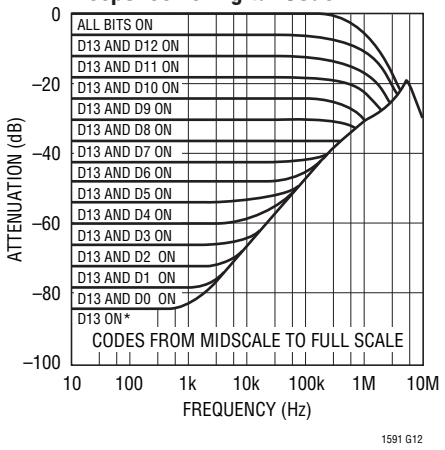



### Unipolar Multiplying Mode Frequency Response vs Digital Code

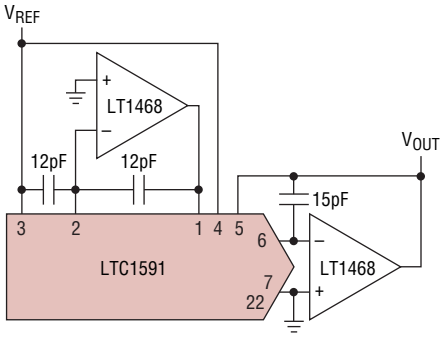


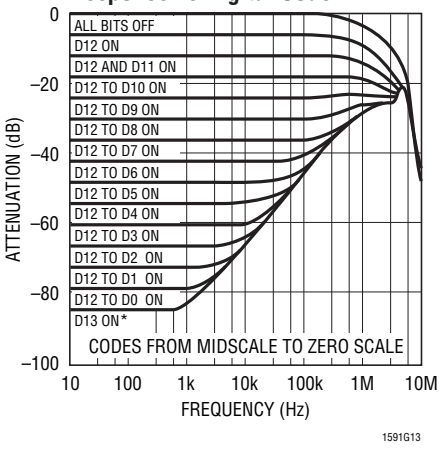

### Bipolar Multiplying Mode Frequency Response vs Digital Code



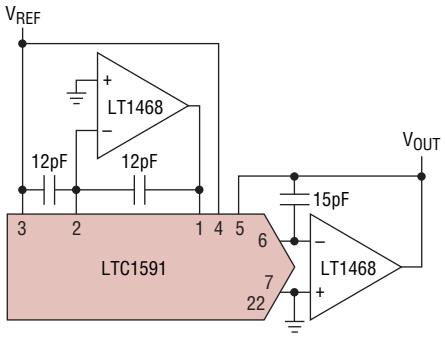

*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO –84dB TYPICAL (–70dB MAX)




### Bipolar Multiplying Mode Frequency Response vs Digital Code

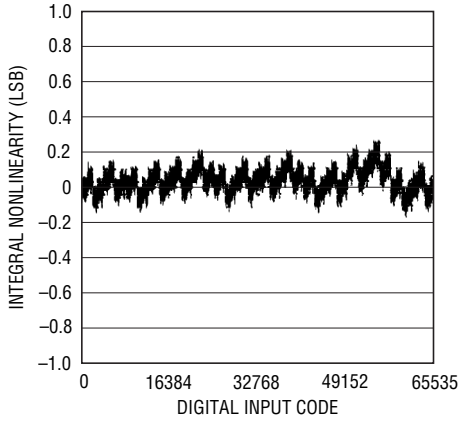



*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO –84dB TYPICAL (–70dB MAX)



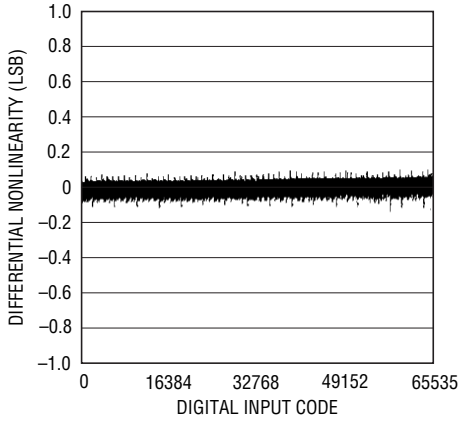
## TYPICAL PERFORMANCE CHARACTERISTICS (LTC1597)

### Integral Nonlinearity (INL)



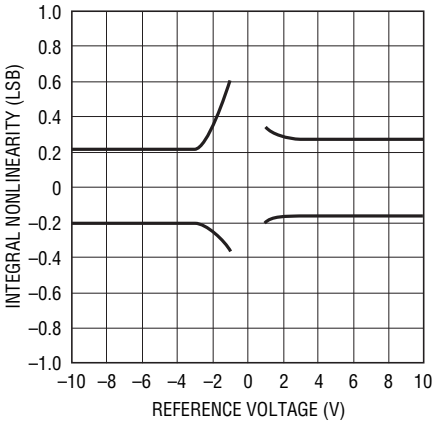

1597 G01

### Differential Nonlinearity (DNL)



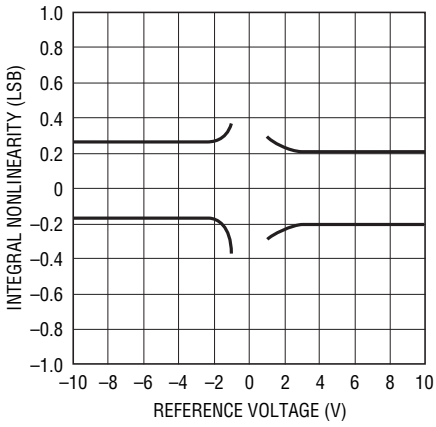

1597 G02

### Integral Nonlinearity vs Reference Voltage in Unipolar Mode



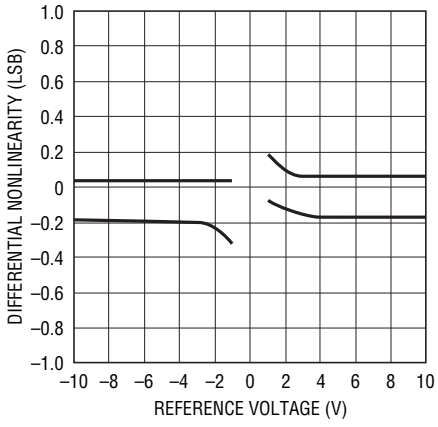

1597 G03

### Integral Nonlinearity vs Reference Voltage in Bipolar Mode



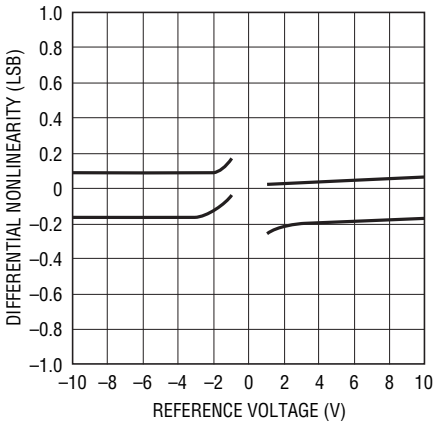

1597 G04

### Differential Nonlinearity vs Reference Voltage in Unipolar Mode



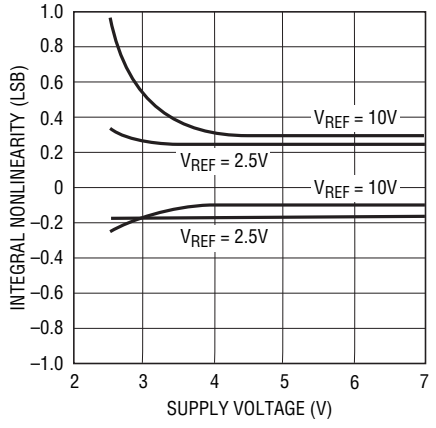

1597 G05

### Differential Nonlinearity vs Reference Voltage in Bipolar Mode



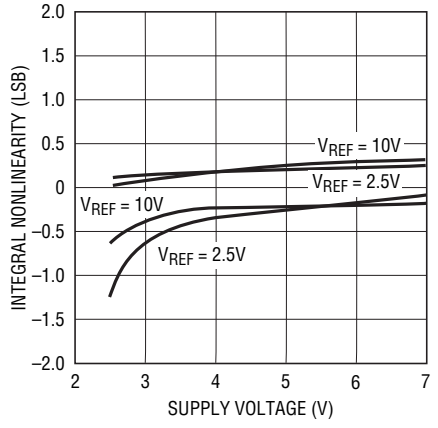

1597 G06

### Integral Nonlinearity vs Supply Voltage in Unipolar Mode



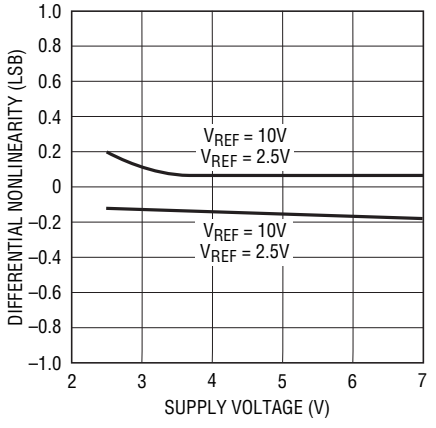

1597 G07

### Integral Nonlinearity vs Supply Voltage in Bipolar Mode




1597 G08

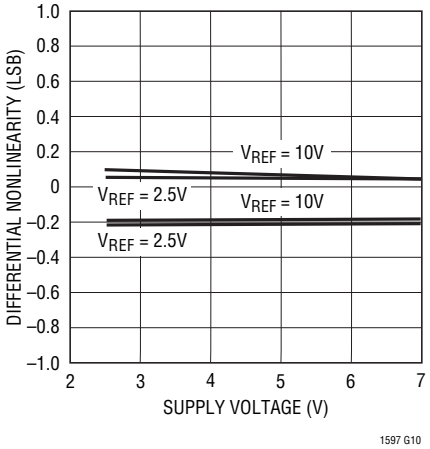
### Differential Nonlinearity vs Supply Voltage in Unipolar Mode



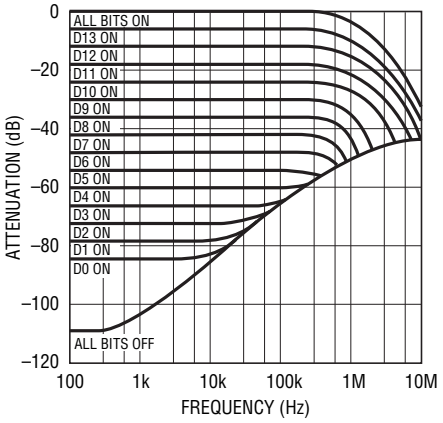

1597 G09

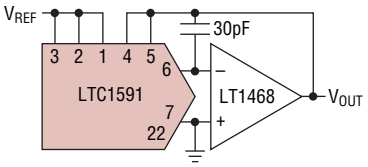
## TYPICAL PERFORMANCE CHARACTERISTICS (LTC1597)

### Differential Nonlinearity vs Supply Voltage in Bipolar Mode

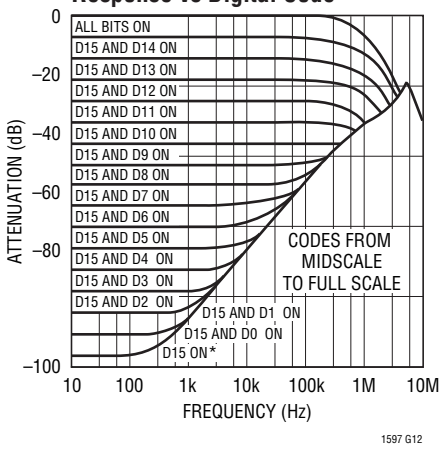



### Unipolar Multiplying Mode Frequency Response vs Digital Code

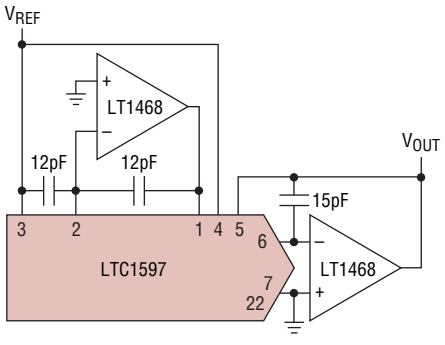


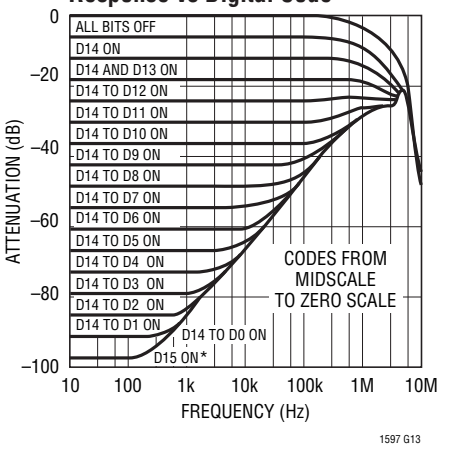

### Bipolar Multiplying Mode Frequency Response vs Digital Code



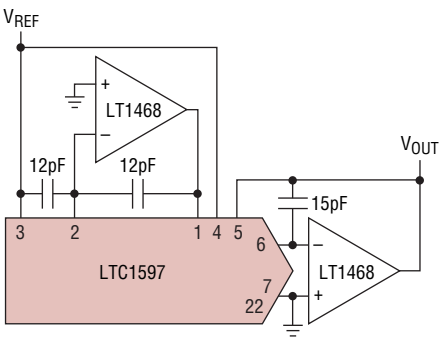

*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO –96dB TYPICAL (–78dB MAX, A GRADE)




### Bipolar Multiplying Mode Frequency Response vs Digital Code




*DAC ZERO VOLTAGE OUTPUT LIMITED BY BIPOLAR ZERO ERROR TO –96dB TYPICAL (–78dB MAX, A GRADE)



# PIN FUNCTIONS

## LTC1591

**REF (Pin 1):** Reference Input and 4-Quadrant Resistor R2. Typically ±10V, accepts up to ±25V. In 2-Quadrant mode this is the reference input. In 4-quadrant mode, this pin is driven by external inverting reference amplifier.

**$R_{COM}$ (Pin 2):** Center Tap Point of the Two 4-Quadrant Resistors R1 and R2. Normally tied to the inverting input of an external amplifier in 4-quadrant operation, otherwise shorted to the REF pin. See Figures 1a and 2a.

**R1 (Pin 3):** 4-Quadrant Resistor R1. In 2-quadrant operation short to the REF pin. In 4-quadrant mode tie to $R_{OFS}$ (Pin 4).

**$R_{OFS}$ (Pin 4):** Bipolar Offset Resistor. Typically swings ±10V, accepts up to ±25V. In 2-quadrant operation tie to $R_{FB}$. In 4-quadrant operation tie to R1.

**$R_{FB}$ (Pin 5):** Feedback Resistor. Normally tied to the output of the current to voltage converter op amp. Swings to $\pm V_{REF}$. $V_{REF}$ is typically ±10V.

**$I_{OUT1}$ (Pin 6):** DAC Current Output. Tie to the inverting input of the current to voltage converter op amp.

**AGND (Pin 7):** Analog Ground. Tie to ground.

**LD (Pin 8):** DAC Digital Input Load Control Input. When LD is taken to a logic high, data is loaded from the input register into the DAC register, updating the DAC output.

**$\overline{WR}$ (Pin 9):** DAC Digital Write Control Input. When $\overline{WR}$ is taken to a logic low, data is loaded from the digital input pins into the 14-bit wide input register.

**DB13 to D2 (Pins 10 to 21):** Digital Input Data Bits.

**DGND (Pin 22):** Digital Ground. Tie to ground.

**$V_{CC}$ (Pin 23):** The Positive Supply Input. $4.5V \leq V_{CC} \geq 5.5V$. Requires a bypass capacitor to ground.

**DB1, DB0 (Pins 24, 25):** Digital Input Data Bits.

**NC (Pins 26, 27):** No Connect.

**$\overline{CLR}$ (Pin 28):** Digital Clear Control Function for the DAC. When $\overline{CLR}$ is taken to a logic low, it sets the DAC output and all internal registers to zero code for the LTC1591 and mid-scale code for the LTC1591-1.

## PIN FUNCTIONS

### LTC1597

**REF (Pin 1):** Reference Input and 4-Quadrant Resistor R2. Typically ±10V, accepts up to ±25V. In 2-Quadrant mode this is the reference input. In 4-quadrant mode, this pin is driven by external inverting reference amplifier.

**$R_{COM}$ (Pin 2):** Center Tap Point of the Two 4-Quadrant Resistors R1 and R2. Normally tied to the inverting input of an external amplifier in 4-quadrant operation, otherwise shorted to the REF pin. See Figures 1b and 2b.

**R1 (Pin 3):** 4-Quadrant Resistor R1. In 2-quadrant operation short to the REF pin. In 4-quadrant mode tie to $R_{OFS}$ (Pin 4).

**$R_{OFS}$ (Pin 4):** Bipolar Offset Resistor. Typically swings ±10V, accepts up to ±25V. In 2-quadrant operation tie to $R_{FB}$. In 4-quadrant operation tie to R1.

**$R_{FB}$ (Pin 5):** Feedback Resistor. Normally tied to the output of the current to voltage converter op amp. Swings to $\pm V_{REF}$. $V_{REF}$ is typically ±10V.

**$I_{OUT1}$ (Pin 6):** DAC Current Output. Tie to the inverting input of the current to voltage converter op amp.

**AGND (Pin 7):** Analog Ground. Tie to ground.

**LD (Pin 8):** DAC Digital Input Load Control Input. When LD is taken to a logic high, data is loaded from the input register into the DAC register, updating the DAC output.

**$\overline{WR}$ (Pin 9):** DAC Digital Write Control Input. When $\overline{WR}$ is taken to a logic low, data is loaded from the digital input pins into the 16-bit wide input register.

**DB15 to D4 (Pins 10 to 21):** Digital Input Data Bits.

**DGND (Pin 22):** Digital Ground. Tie to ground.

**$V_{CC}$ (Pin 23):** The Positive Supply Input. $4.5V \leq V_{CC} \geq 5.5V$. Requires a bypass capacitor to ground.

**DB3 to DB0 (Pins 24 to 27):** Digital Input Data Bits.

**$\overline{CLR}$ (Pin 28):** Digital Clear Control Function for the DAC. When $\overline{CLR}$ is taken to a logic low, it sets the DAC output and all internal registers to zero code for the LTC1597 and mid-scale code for the LTC1597-1.

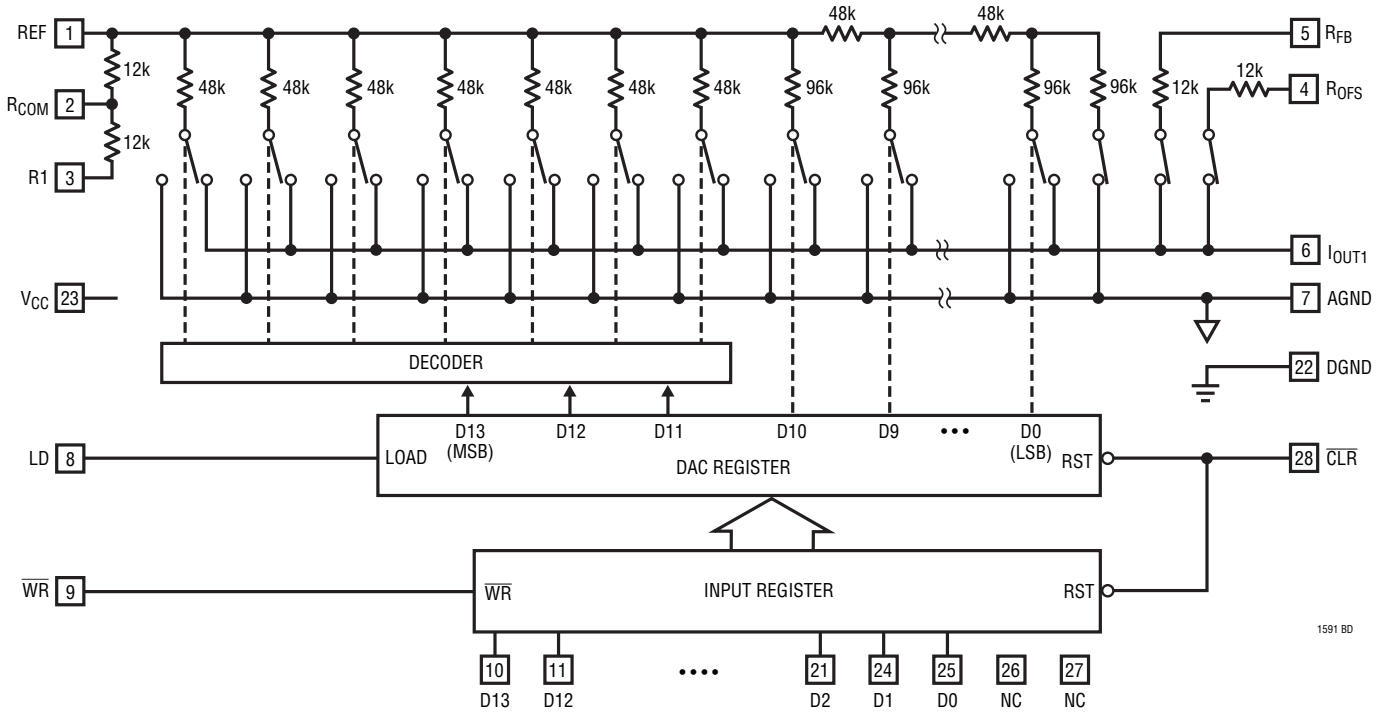
## TRUTH TABLE

**Table 1**

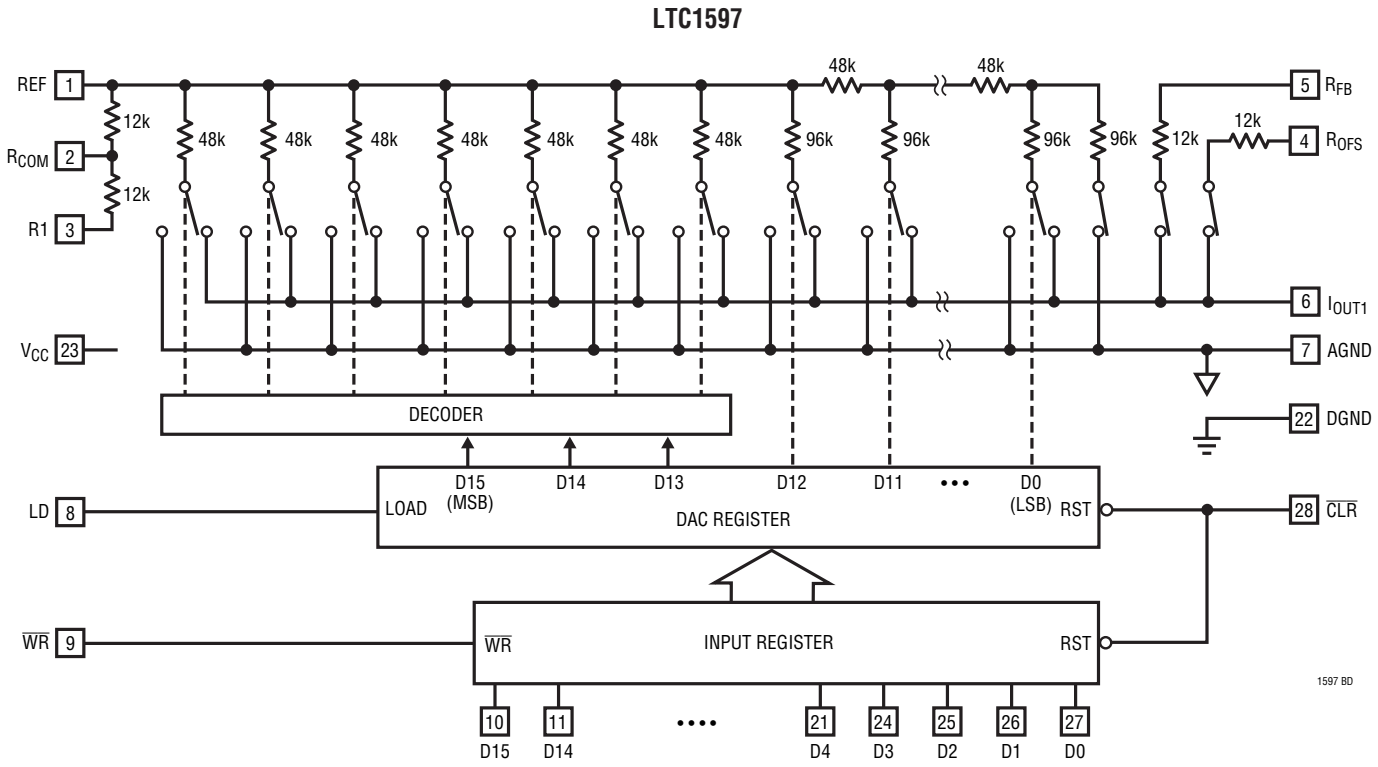
| CONTROL INPUTS | | | |
|---|---|---|---|
| $\overline{CLR}$ | $\overline{WR}$ | LD | REGISTER OPERATION |
| 0 | X | X | Reset Input and DAC Register to All 0s for LTC1591/LTC1597 and Mid-Scale for LTC1591-1/LTC1597-1 (Asynchronous Operation) |
| 1 | 0 | 0 | Load Input Register with All 14/16 Data Bits |
| 1 | 1 | 1 | Load DAC Register with the Contents of the Input Register |
| 1 | ⌐¬ | ⌐¬ | Input and DAC Register Are Transparent |
| 1 | | | CLK = LD and $\overline{WR}$ Tied Together. The 14/16 Data Bits Are Loaded into the Input Register on the Falling Edge of the CLK and Then Loaded into the DAC Register on the Rising Edge of the CLK |
| 1 | 1 | 0 | No Register Operation |

## BLOCK DIAGRAMS

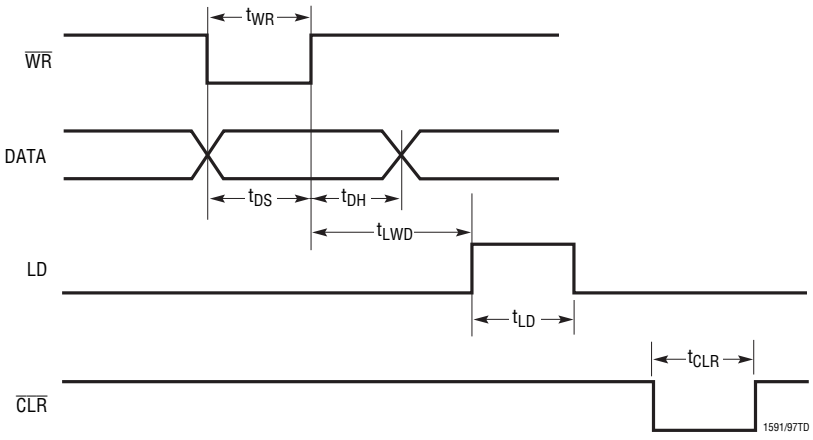
**LTC1591**



## BLOCK DIAGRAMS




## TIMING DIAGRAM



# APPLICATIONS INFORMATION

## Description

The LTC1591/LTC1597 are 14-/16-bit multiplying, current output DACs with a full parallel 14-/16-bit digital interface. The devices operate from a single 5V supply and provide both unipolar 0V to –10V or 0V to 10V and bipolar ±10V output ranges from a 10V or –10V reference input. They have three additional precision resistors on chip for bipolar operation. Refer to the block diagrams regarding the following description.

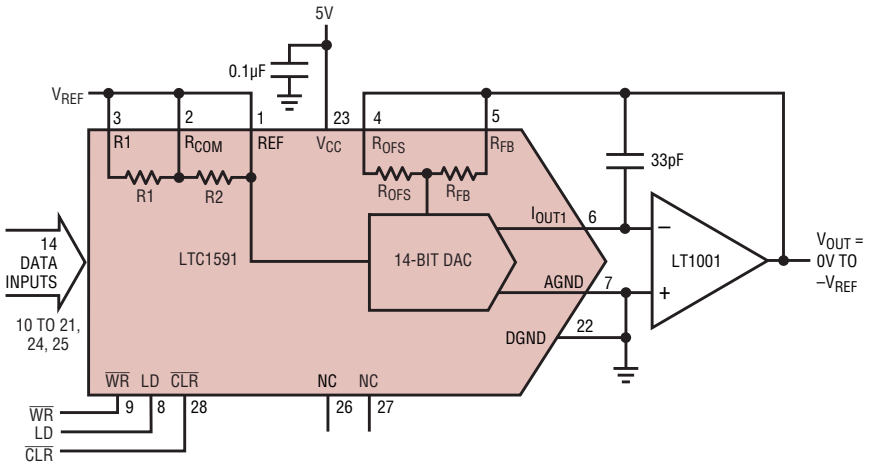
The 14-/16-bit DACs consist of a precision R-2R ladder for the 11/13LSBs. The 3MSBs are decoded into seven segments of resistor value R. Each of these segments and the R-2R ladder carries an equally weighted current of one eighth of full scale. The feedback resistor $R_{FB}$ and 4-quadrant resistor $R_{OFS}$ have a value of R/4. 4-quadrant resistors R1 and R2 have a magnitude of R/4. R1 and R2 together with an external op amp (see Figure 2) inverts the reference input voltage and applies it to the 14-/16-bit DAC input REF, in 4-quadrant operation. The REF pin presents a constant input impedance of R/8 in unipolar mode and R/12 in bipolar mode. The output impedance of the current output pin $I_{OUT1}$ varies with DAC input code. The $I_{OUT1}$ capacitance due to the NMOS current steering switches also varies with input code from 70pF to 115pF. An added feature of these devices, especially for waveform generation, is a proprietary deglitcher that reduces glitch energy to below 2nV-s over the DAC output voltage range.

## Digital Section

The LTC1591/LTC1597 are 14-/16-bit wide full parallel data bus inputs. The devices are double-buffered with two 14-/16-bit registers. The double-buffered feature permits the update of several DACs simultaneously. The input register is loaded directly from a 16-bit microprocessor bus when the $\overline{WR}$ pin is brought to a logic low level. The second register (DAC register) is updated with the data from the input register when the LD pin is brought to a logic high level. Updating the DAC register updates the DAC output with the new data. To make both registers transparent for flowthrough mode, tie $\overline{WR}$ low and LD high. However, this defeats the deglitcher operation and output glitch impulse may increase. The deglitcher is activated on the rising edge of the LD pin. The versatility of the interface also allows the use of the input and DAC registers in a master slave or edge-triggered configuration. This mode of operation occurs when $\overline{WR}$ and LD are tied together. The asynchronous clear pin resets the LTC1591/LTC1597 to zero scale and the LTC1591-1/LTC1597-1 to mid-scale. $\overline{CLR}$ resets both the input and DAC registers. These devices also have a power-on reset. Table 1 shows the truth table for the LTC1591/LT1597.

## Unipolar Mode (2-Quadrant Multiplying, $V_{OUT}$ = 0V to $-V_{REF}$)

The LTC1591/LTC1597 can be used with a single op amp to provide 2-quadrant multiplying operation as shown in Figure 1. With a fixed –10V reference, the circuits shown give a precision unipolar 0V to 10V output swing.




**Unipolar Binary Code Table**

| DIGITAL INPUT BINARY NUMBER IN DAC REGISTER | | | | ANALOG OUTPUT VOUT |
|---|---|---|---|---|
| MSB | | | LSB | |
| 1111 | 1111 | 1111 | 11 | $-V_{REF}$ (16,383/16,384) |
| 1000 | 0000 | 0000 | 00 | $-V_{REF}$ (8,192/16,384) = $-V_{REF}/2$ |
| 0000 | 0000 | 0000 | 01 | $-V_{REF}$ (1/16,384) |
| 0000 | 0000 | 0000 | 00 | 0V |

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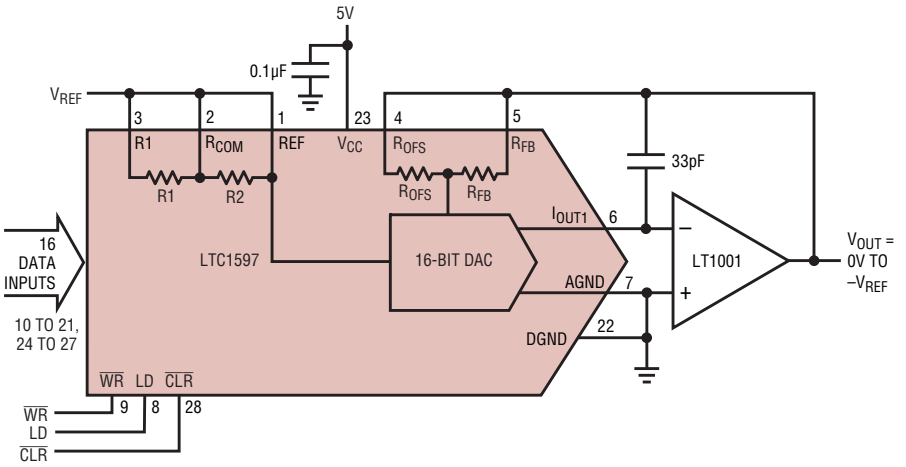
**Figure 1a. Unipolar Operation (2-Quadrant Multiplication) $V_{OUT}$ = 0V to $-V_{REF}$**

## APPLICATIONS INFORMATION




**Unipolar Binary Code Table**

| DIGITAL INPUT BINARY NUMBER IN DAC REGISTER | | | | ANALOG OUTPUT VOUT |
|---|---|---|---|---|
| MSB | | | LSB | |
| 1111 | 1111 | 1111 | 1111 | $-V_{REF}$ (65,535/65,536) |
| 1000 | 0000 | 0000 | 0000 | $-V_{REF}$ (32,768/65,536) = $-V_{REF}/2$ |
| 0000 | 0000 | 0000 | 0001 | $-V_{REF}$ (1/65,536) |
| 0000 | 0000 | 0000 | 0000 | 0V |

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**Figure 1b. Unipolar Operation (2-Quadrant Multiplication) $V_{OUT}$ = 0V to $-V_{REF}$**

### Bipolar Mode (4-Quadrant Multiplying, $V_{OUT} = -V_{REF}$ to $V_{REF}$)

The LTC1591/LTC1597 contain on chip all the 4-quadrant resistors necessary for bipolar operation. 4-quadrant multiplying operation can be achieved with a minimum of external components, a capacitor and a dual op amp, as shown in Figure 2. With a fixed 10V reference, the circuit shown gives a precision bipolar –10V to 10V output swing.

### Op Amp Selection

Because of the extremely high accuracy of the 14-/16-bit LTC1591/LTC1597, thought should be given to op amp selection in order to achieve the exceptional performance of which the part is capable. Fortunately, the sensitivity of INL and DNL to op amp offset has been greatly reduced compared to previous generations of multiplying DACs.

Op amp offset will contribute mostly to output offset and gain and will have minimal effect on INL and DNL. For the LTC1597, a 500µV op amp offset will cause about 0.55LSB INL degradation and 0.15LSB DNL degradation with a 10V full-scale range. The main effects of op amp offset will be a degradation of zero-scale error equal to the op amp offset, and a degradation of full-scale error equal to twice the op amp offset. For the LTC1597, the same 500µV op amp offset (2mV offset for LTC1591) will cause a 3.3LSB zero-scale error and a 6.5LSB full-scale error with a 10V full-scale range.

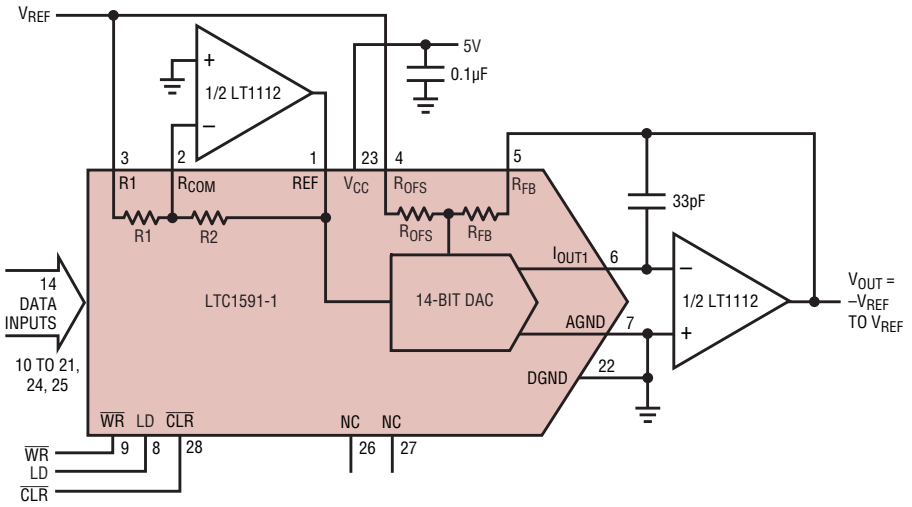
Op amp input bias current ($I_{BIAS}$) contributes only a zero-scale error equal to $I_{BIAS}(R_{FB}/R_{OFS}) = I_{BIAS}(6k)$. For a thorough discussion of 16-bit DAC settling time and op amp selection, refer to Application Note 74, "*Component and Measurement Advances Ensure 16-Bit DAC Settling Time.*"

### Reference Input and Grounding

For optimum performance the reference input of the LTC1597 should be driven by a source impedance of less than 1kΩ. However, these DACs have been designed to minimize source impedance effects. An 8kΩ source impedance degrades both INL and DNL by 0.2LSB.

As with any high resolution converter, clean grounding is important. A low impedance analog ground plane and star grounding should be used. AGND must be tied to the star ground with as low a resistance as possible.

## APPLICATIONS INFORMATION

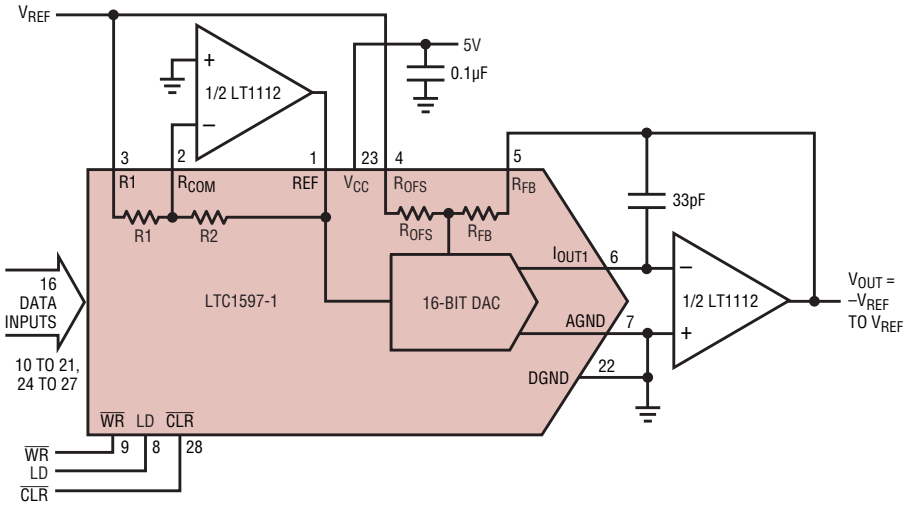



**Bipolar Offset Binary Code Table**

| DIGITAL INPUT BINARY NUMBER IN DAC REGISTER | | | | ANALOG OUTPUT $V_{OUT}$ |
|---|---|---|---|---|
| MSB | | | LSB | |
| 1111 | 1111 | 1111 | 11 | $V_{REF}$ (8,191/8,192) |
| 1000 | 0000 | 0000 | 01 | $V_{REF}$ (1/8,192) |
| 1000 | 0000 | 0000 | 00 | 0V |
| 0111 | 1111 | 1111 | 11 | $-V_{REF}$ (1/8,192) |
| 0000 | 0000 | 0000 | 00 | $-V_{REF}$ |

1591/97 F02a

**Figure 2a. Bipolar Operation (4-Quadrant Multiplication) $V_{OUT} = -V_{REF}$ to $V_{REF}$**




**Bipolar Offset Binary Code Table**

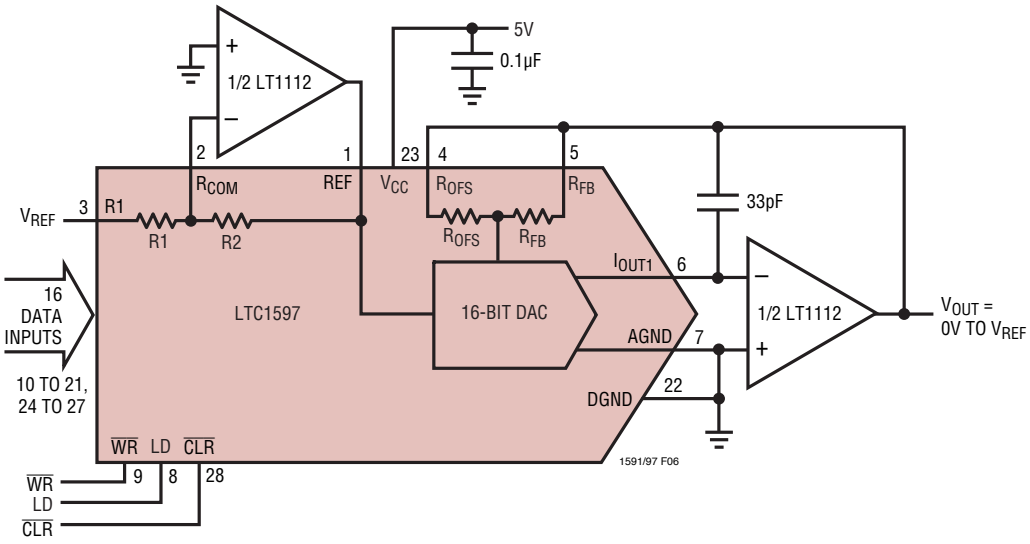
| DIGITAL INPUT BINARY NUMBER IN DAC REGISTER | | | | ANALOG OUTPUT $V_{OUT}$ |
|---|---|---|---|---|
| MSB | | | LSB | |
| 1111 | 1111 | 1111 | 1111 | $V_{REF}$ (32,767/32,768) |
| 1000 | 0000 | 0000 | 0001 | $V_{REF}$ (1/32,768) |
| 1000 | 0000 | 0000 | 0000 | 0V |
| 0111 | 1111 | 1111 | 1111 | $-V_{REF}$ (1/32,768) |
| 0000 | 0000 | 0000 | 0000 | $-V_{REF}$ |

1591/97 F02b

**Figure 2b. Bipolar Operation (4-Quadrant Multiplication) $V_{OUT} = -V_{REF}$ to $V_{REF}$**

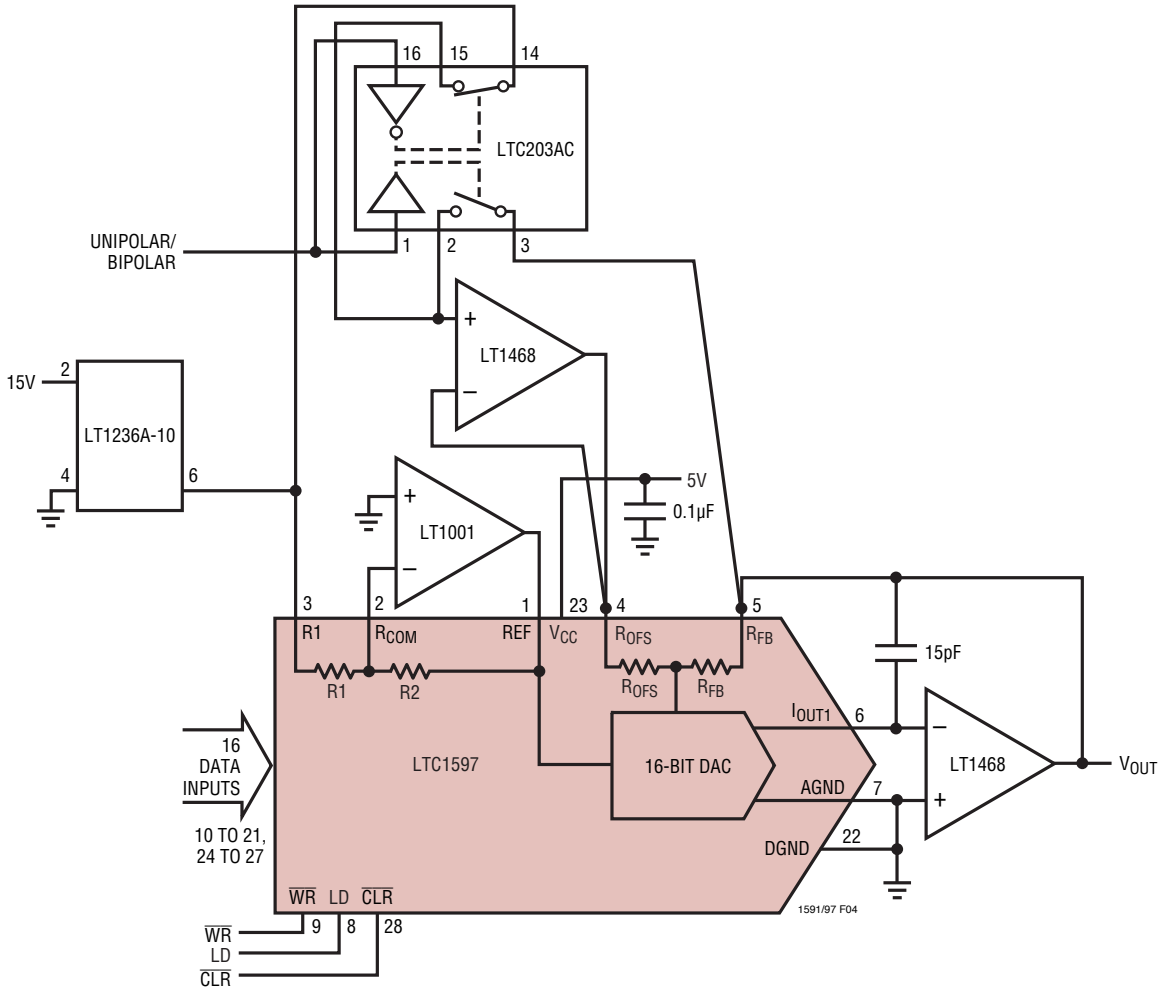
## TYPICAL APPLICATIONS

**Noninverting Unipolar Operation (2-Quadrant Multiplication) $V_{OUT}$ = 0V to $V_{REF}$**



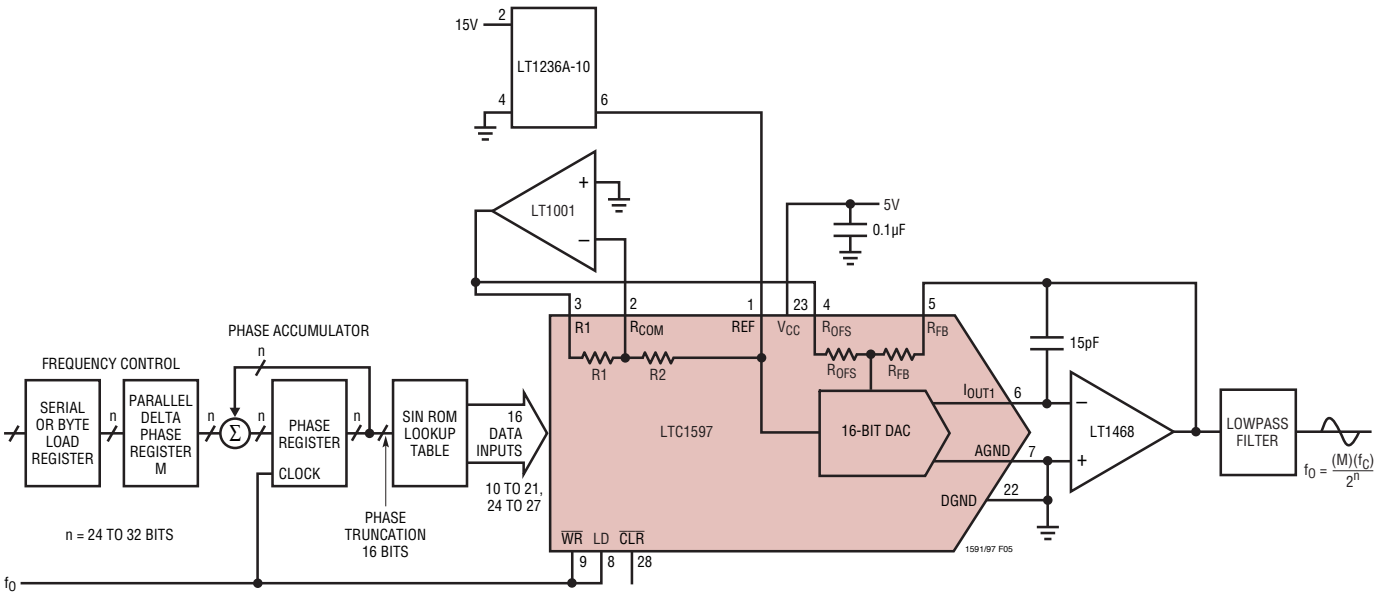
## TYPICAL APPLICATIONS

**16-Bit $V_{OUT}$ DAC Programmable Unipolar/Bipolar Configuration**



## TYPICAL APPLICATIONS

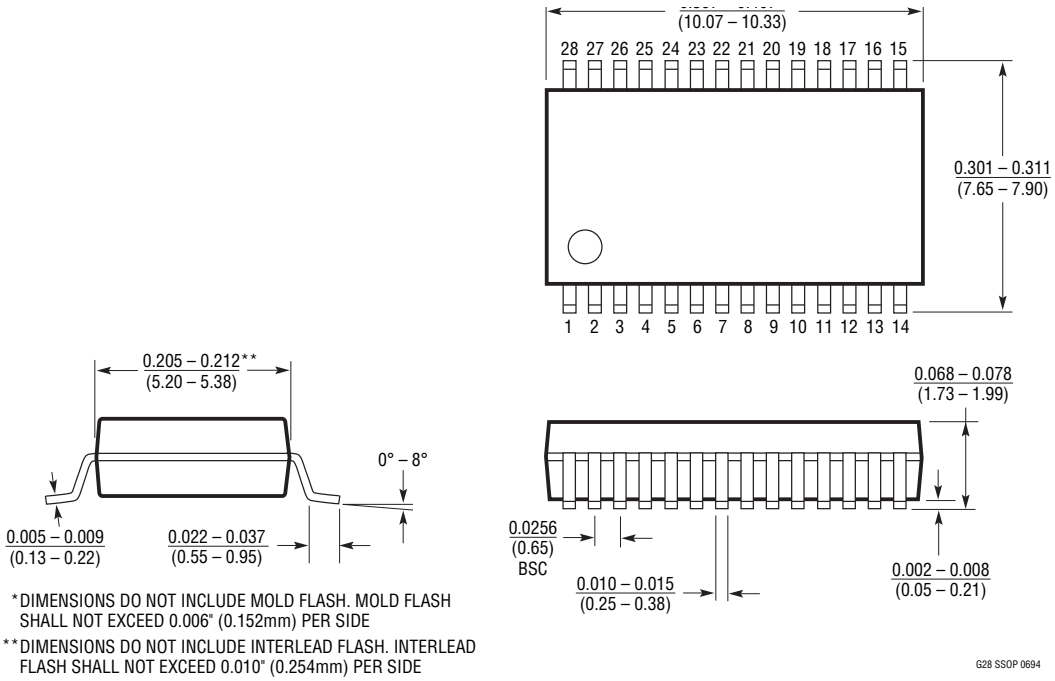
### Digital Waveform Generator



## PACKAGE DESCRIPTION

**Dimensions in inches (millimeters) unless otherwise noted.**
**Please refer to http://www.linear.com/designtools/packaging/ for the most recent package drawings.**

**G Package**
**28-Lead Plastic SSOP (0.209)**
(LTC DWG # 05-08-1640)



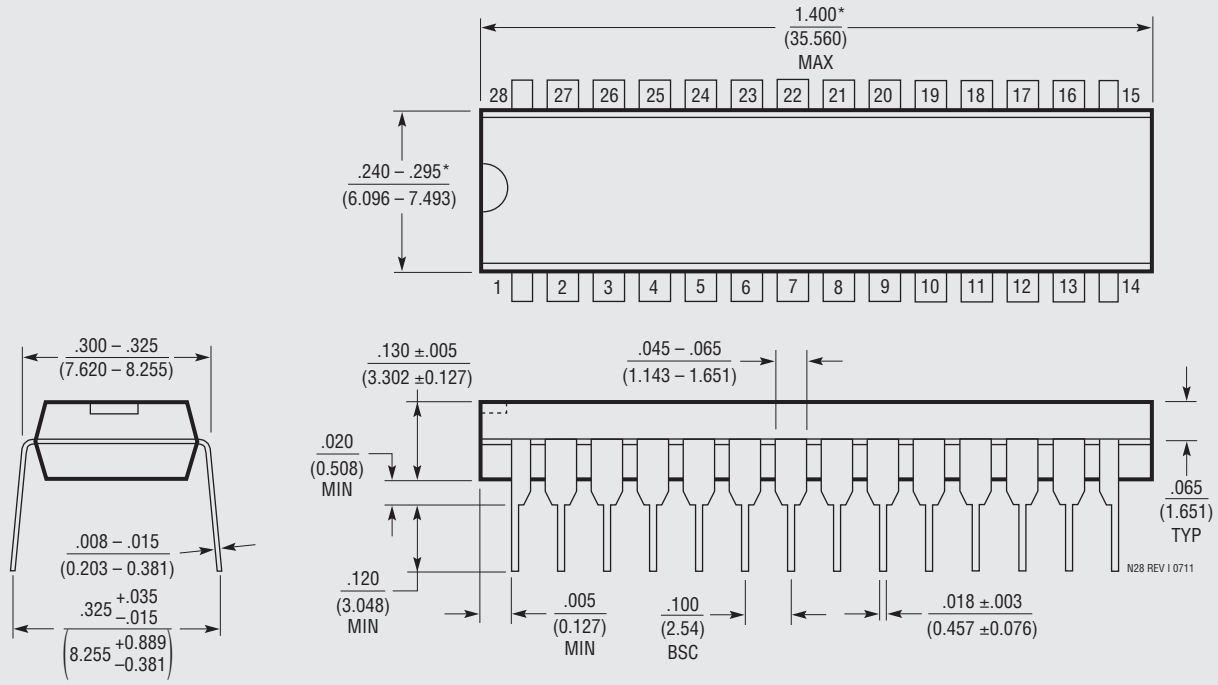

*DIMENSIONS DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSIONS DO NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

## PACKAGE DESCRIPTION

**Dimensions in inches (millimeters) unless otherwise noted.**
**Please refer to http://www.linear.com/designtools/packaging/ for the most recent package drawings.**

**N Package**
**28-Lead Plastic PDIP (Narrow 0.300 Inch)**
(LTC DWG # 05-08-1510 Rev I)




NOTE:
1. DIMENSIONS ARE INCHES / MILLIMETERS

*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH (0.254mm)

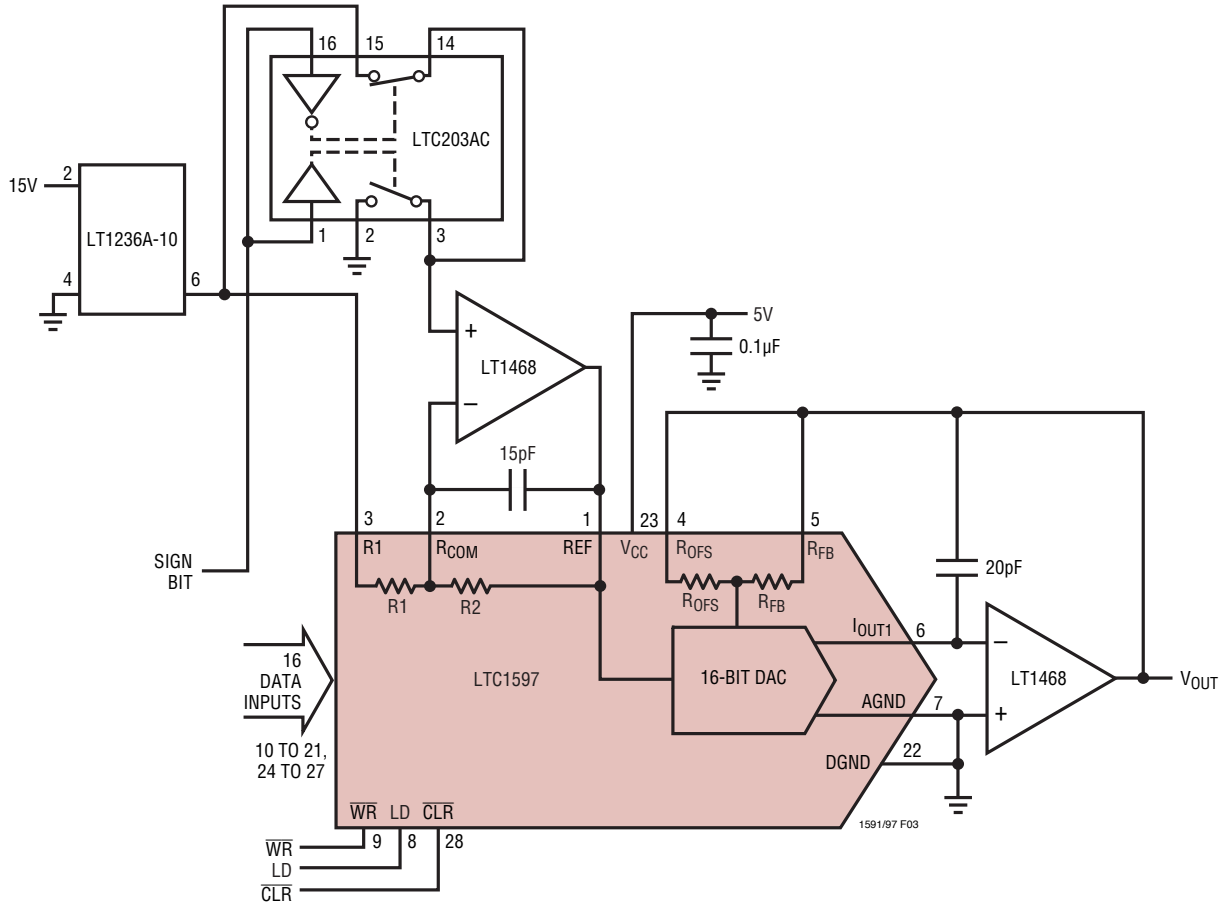
**OBSOLETE PACKAGE**

## REVISION HISTORY (Revision history begins at Rev B)

| REV | DATE | DESCRIPTION | PAGE NUMBER |
|---|---|---|---|
| B | 07/15 | Obsoleted 28-Lead PDIP Package | 2, 3, 22 |

## TYPICAL APPLICATION

**17-Bit Sign Magnitude DAC with Bipolar Zero Error of 140µV (0.92LSB at 17 Bits) at 25°C**




## RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|---|---|---|
| **Op Amps** | | |
| LT®1001 | Precision Operational Amplifier | Low Offset, Low Drift |
| LT1112 | Dual Low Power, Precision Picoamp Input Op Amp | Low Offset, Low Drift |
| LT1468 | 90MHz, 22V/µs, 16-Bit Accurate Op Amp | Precise, 1µs Settling to 0.0015% |
| **DACs** | | |
| LTC1595/LTC1596 | Serial 16-Bit Current Output DACs | Low Glitch, ±1LSB Maximum INL, DNL |
| LTC1650 | Serial 16-Bit Voltage Output DAC | Low Noise and Glitch Rail-to-Rail $V_{OUT}$ |
| LTC1658 | Serial 14-Bit Voltage Output DAC | Low Power, 8-Lead MSOP Rail-to-Rail $V_{OUT}$ |
| **ADCs** | | |
| LTC1418 | 14-Bit, 200ksps 5V Sampling ADC | 16mW Dissipation, Serial and Parallel Outputs |
| LTC1604 | 16-Bit, 333ksps Sampling ADC | ±2.5V Input, SINAD = 90dB, THD = 100dB |
| LTC1605 | Single 5V, 16-Bit 100ksps ADC | Low Power, ±10V Inputs |
| **References** | | |
| LT1236 | Precision Reference | Ultralow Drift, 5ppm/°C, High Accuracy 0.05% |


Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408) 432-1900 • FAX: (408) 434-0507 • www.linear.com
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